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 **COURSE NAME:**

**(ENVIRONMENTAL TOXICOLOGY ETO 628)**

 **Assignment Title:**

**(STUDENT’S COURSEWORK)**

**ATLANTIC INTERNATIONAL UNIVERSITY**

 **JANUARY 2024**

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**INTRODUCTION**

Chemical substances in the environment are classified using their hazardous properties. Eight such key hazard classes are identified, among which are; explosives, flammable gases, corrosive substances, substances toxic to people and substances toxic to the environment to mention but a few. A substance is regarded toxic when it can harm people if it enters the body through contact, being inhaled or ingested. The effects of a toxic substance can range from mild to life threatening, and can be immediate or long term.

This course is focused on toxic substances in the environment, their sources, harmful effects, ways of detecting and testing them, and the management of ecological toxicology system. **Toxicology is the study of the harmful impacts of the chemical, biological, and physical substances or agents on living things, particularly human beings**. (https//:www.publichealth.columbia.edu/news/what- toxicology, 2020). When the focus of the study of the effects of chemical agents in the environment is on humans it defines environmental toxicology.

Environmental toxicology is therefore a multidisciplinary field of science that is responsible for the study of the harmful effects of chemical or biological pollutants on living organisms. On the broader scale, it is the study of the effects of pollutants upon the structure and function of ecological systems i.e. from the molecular to the individual organism to the community and to the ecosystem and finally the landscape. A multidisciplinary approach involving a variety of specialists describes the broad scope of environmental toxicology.

In making decisions about the management of ecological systems these specialists interact with a variety of other people, such as; the decision and policy makers, the public, educators, and other key individuals. Environmental toxicology interrelates with a variety of disciplines such as terrestrial and aquatic ecologists, geneticists, chemists, mathematicians, and molecular biologists, which collectively play an important role in the evaluation of the impacts of chemicals on biological system.

 **DESCRIPTION OF COURSE**

This subject shall be treated under the following headings:

Introduction to Environmental Toxicology

What is environmental toxicology?

Environmental Toxicology as an Interdisciplinary Science

The roles of the scientific community in the field of environmental toxicology

Categories of toxicology

Factors that affect toxicity

Bioaccumulation/Biotransformation/Biodegradation

Single phase contaminant transport (air, water, soil)

Chemical interactions

Types of toxic effects

Dose-response relationship

Quantitative risk assessment: dose – rate terminologies

Reference dose

ADME process

  **GENERAL ANALYSIS**

Traditionally, toxicology is defined as the study of the harmful effects of chemicals, drugs, and chemical mixtures on living organisms. The environmental branch of toxicology has assumed a wider meaning within the past two decades. An example is the use of poisons which is as old as the human race. Primitive people for centuries used toxic plant extracts to poison their arrows for hunting and warfare. Our civilization has seen poisons being studied and used for financial, political, or marital advantages.

The credit for elevating toxicology to a true science goes to a Spanish physician, Mattieu Joseph Benaventura Orfila (1787–1853), who first described the correlation between the persistence of chemicals in the body and their physiological effect. He also developed analytical testing methods to detect the presence of toxins in the body and devised certain antidotal therapies. Contemporary toxicology has evolved into a study with three branches: Clinical toxicology is concerned with the effect of drugs on human patients. Forensic toxicology is concerned with the detection, for judicial purposes, of the unlawful use of toxic agents. . Environmental toxicology is concerned with the effects of toxins, whether purposely applied (such as pesticides) or derived from industrial processes, on health and the environment.

Environmental toxicology is the study of the effects of environmental toxicants on health and the environment. Environmental toxicants are pollutants released into the environment that can cause adverse effects on the health of living organisms, including plants, animals, and humans. The subject of environmental toxicology is borne out of the recognition that; (i) human survival is hinged on the well-being of other species and on the availability of food, clean air, and water; and (ii) naturally occurring chemicals as well as anthropogenic chemicals as can cause detrimental effects on living organisms and ecological processes. (Yu, 2005). Therefore, the study of environmental toxicology is concerned with how environmental toxicants influence the health and welfare of plants, animals, and humans through their interaction with them.

Environmental toxicology is relatively a new discipline. It was first brought forward at the 37th annual meeting sponsored by the Society of Environmental Toxicology and Chemistry (SETAC) in North America in 2016. (Wayne G.Landis, Ruth M.Sofield, Ming-Ho Yu, 2018). The science of environmental toxicology evolved from the efficacy testing of pesticides in the 1940s to the cleanup of burning rivers, polluted lakes, and wildlife kills of the 1960s. The establishment of the United States Environmental Protection Agency (USEPA) and the passage of the National Environmental Policy Act forced the rapid development of this field.

Since World War II enormous industrial and economic development has taken place. One example of such development took place in the chemicals industry, resulting in the manufacture of a large number of chemical products. Many of these products, particularly fertilizers, insecticides, and herbicides immediately gained worldwide acceptance. The introduction of fertilizers, together with the development of new high-yield grains, caused dramatic increases in world food production. This remarkable milestone is widely known as the Green Revolution. This increase in food production, together with technological advancement and rise in industrial output, led to an overall global economic expansion and significant increases in gross national product (GNP) in many countries. These developments, accompanied by improved medicine and medical science and technology, helped improve general public health, life expectancy and infant mortality.

Environmental toxicology is a multidisciplinary science which involves a number of widely diverse areas of study such as; chemistry - the toxins characterization; pharmacology - the mode of penetration and distribution of toxins in the body; biochemistry - the interaction and metabolism of toxins with cell components; physiology - the impacts of toxins on body organs; biology - the impact of toxins on the environment; genetics - the influence toxins can have on the reproductive system as well as on future generations by altering genetic codes; epidemiology - the impact on the whole population due to chronic exposure to small quantities of suspected chemicals; law – regulation and control of the use or release into the environment of toxic substances; and economics - evaluating environmental cost side by side with the benefit of economic development and determining trade-offs among economy, health, and the environment; Organic chemistry - the basic language and the foundation of both the abiotic and biotic interactions within an ecosystem; Biostatistics - the application of statistics to biological problems, provides the tools for data analysis and hypothesis testing; and Mathematical and computer modeling which enables the researcher to predict the effects and to increase the rigor of a hypothesis.

**ACTUALIZATION AND DISCUSSION**

This topic on environmental toxicology is intended to be comprehensively treated in the form of questions and answers. Below are some questions and answers to deal with the subject matter.

**1a. What is environmental toxicology?**

Environmental toxicology can be defined as the study of the harmful effects of chemicals such as drugs, and other chemical mixtures on living organisms. It is the study of the effects of pollutants on the structure and performance of ecological systems. As a field of science, environmental toxicology includes for example; the impact of agricultural pesticides on animals and humans exposed to vegetation on which they have been used either in-field or post -harvest. Therefore, toxicology can easily be defined as the science of poisons.

(https://www.safeopedia.com/definition/5992/environmental-toxicology) (group, 2019)

**1b. What are examples of toxins?**

Britannica defines toxins as substances which are poisonous to living organisms. They may be produced by living organisms such as bacteria, algae, fungi, plants, and animals. They can also be produced by sources such as industrial chemicals, pesticides, and heavy metals. Awareness of the potential sources of toxins is very important so that steps can be taken to minimize exposure to them.

Some examples of toxins include:

* **Botulinum toxin**: it is produced by the bacterium Clostridium botulinum which causes botulism, a rare but serious illness that can lead to paralysis and death in humans
* **Tetrodotoxin:** is a potent neurotoxin found in the organs of pufferfish, which can cause paralysis and death in humans.
* **Aflatoxins**: they are products of certain species of fungi, which can contaminate food crops such as, corn, tree nuts and peanuts , they are carcinogenic and capable of causing liver damage
* **Ricin:** it is a toxic protein found in the seeds of the castor oil plant which is capable of causing severe gastrointestinal symptoms, seizures, and even, death.
* **Lead**: this is a heavy metal found in contaminated soil, water, and air. It is capable of causing developmental distortion/delays, learning difficulties, and other health hazards.

**2a. Why is environmental toxicology considered a broad, multidisciplinary field of study?**

Environmental toxicology is considered as a broad, multidisciplinary field of study because it requires a variety of specialists from different disciplines working together to effectively deal with the broad scope of the subject. The various specialists interact with a variety of other people, including educators, decision and policy makers, the public, and other key individuals in making decisions about the management of ecological systems and the services they provide.

**2b. List seven disciplines that are combined in environmental toxicology**

Some of the disciplines that are combined in environmental toxicology are:

1. Terrestrial and aquatic ecology

2. Chemistry

 3. Molecular biology

 4. Genetics

 5. Mathematics

 6. Pharmacokinetics

7. Statistics and data analysis

**3. What part does the scientific community have in the field of environmental toxicology?**

The scientific community as a basic research field of environmental toxicology carries out the following roles:

 Publication of science journals

 Participation in the peer review process

 Setting up Panels of Review

 Organizing Scientific Societies

**4. Highlight the major difference between toxicology and pharmacology.**

The main difference between the two lies in the fact that while toxicology focuses on the adverse effects of chemical substances on living organisms, pharmacology focuses on the potential therapeutic application of the benefits of chemical substances on living organisms.

**5a. What are the various categories of toxicology?**

Four different categories of toxicology are identified as itemized below:

1. Molecular toxicology – it focuses on cellular, biochemical and molecular activities such as drug development, natural products and insecticide development.
2. Regulatory toxicology – it focuses on risk assessment deployed to determine the health risks of a substance. For example regulatory agencies rely on toxicology in the following ways:
* FDA(Food and Drug Administration) - to determine what can be sold
* EPA (Environmental Protection Agency )- to determine the acceptable level of certain chemical substances in the environment
* OSHA (Occupational Safety and Health Administration) – to detect chemical substances and allowable concentrations in contact with humans.
* DOT (Department of Transportation) – to determine materials shipped across nations in interstate commerce, in order to label and package them accordingly.
1. Forensic toxicology- it deals with medico-legal aspects of the adverse effects of drugs on humans or animals. It conducts postmortem investigation to establish the circumstances surrounding the death and the real cause of death of a human or an animal.
2. Clinical toxicology – it focuses on the diseases caused by toxic substances, disintoxication treatments or techniques, and as physician in poison management and emergency medicine.

**5b. How do you define ecotoxicology?**

Ecotoxicology deals with the effects of pollutants or toxic substances on population dynamics in an ecosystem.

6a. Enumerate the various factors that affect toxicity.

Factors that affect toxicity are here listed and also presented in a chart format:

* Period or time of exposure
* Chemical substances
* Chemical interactions
* Route of exposure
* Subject susceptibilities
* Sources of exposure: through air, water, soil, and crops.
* Concentration or dose

FACTORS AFFECTING TOXICITY

**Chart 1**

**6b. List three categories of toxic effect based on period or time of exposures**

Based on the period or duration of exposure toxicity can be classified into three namely;

1. Acute – this is toxicity from a brief or single period of time (between 1-14 days)
2. Subchronic – this is toxicity from continuous or repeated exposures, mostly from weeks to several months (between 14 – 365 days)
3. Chronic – this is toxicity from exposure that lasts for a long period of time; years or lifetime.

**7a. Considering the transportation of a single phase contaminant through air what are the important facts to note?**

Some important facts worthy of note when discussing the transportation of contaminants through air are:

1. The primary routes of contaminants into the air are through evaporation, stack emission and air release.
2. Contaminants with low viscosity move faster in the atmosphere than in water.

**7b. what factors are responsible for the diffusivity of contaminants in the air?**

Diffusivity of contaminants depends on:

1. Molecular weight of contaminants relative to air
2. Air temperature
3. Wind currents
4. Energy generated by molecular interaction
5. Heat transfer from the ground.

In the form of a chart,

**Chart 2**

**7c. Enumerate the various factors responsible for the diffusivity of contaminants in water.**

Contaminants penetrate water by direct applications, spills, deposition (wet and dry) and inter-phase movement.

Diffusivity of contaminants depends on:

1. Soil proximity and water layers.
2. The temperature of the water
3. Molecular weight of the contaminant relative to water
4. Concentration and solubility.
5. Contaminant may be hydrophilic or oligotrophic

**8. what are the factors to consider when examining the transport of contaminants in the soil?**

Soil porosity varies with composition (silt, sand, clay, organic materials). While in the soil the transport of the contaminant depends on:

1. Molecular weight
2. Soil particle size
3. The temperature of the soil
4. Concentration gradient
5. Length of path

**9. Explain the context of chemical (contaminant) bioavailability and chemical interactions.**

It is not the entire amount of chemical contaminant introduced into the environment that get uptaken by organism but only a portion. This is because organic chemicals in the environment undergo biotransformation which subsequently affects their bioavailability i.e. the amount of that substance present in the environment at a given time. For example, when considering the administration by oral gavage of a test compound that is highly metabolized by the liver versus subcutaneous injection will most likely result in less parent compound present in the systemic circulation.

Chemical interactions may occur by:

* Administration of multiple drugs to a patients daily
* Daily use of multiple healthcare products
* Simultaneous workplace exposure.

Chemical interactions of two or more substances may produce:

1. Antagonistic effects leading to reduction of toxicity
2. Synergistic effects resulting in increased toxicity of some chemicals. e.g exposure to asbestos and cigarette smoking can result in lung cancer.

 **10a. Differentiate between specific and systemic toxic effects.**

Toxicity directed to particular tissues or organs which are referred to as target tissues or target organs is regarded as **specific toxic effect**. When toxicity has general effects on cells, organs, and the entire body it is regarded as **systemic toxic effect**. (Ph.D., 2018) (Gurjar B. R., 2018)

**10b. Explain in simple and understandable terms the concept of dose-response relationship.**

**Dose–Response Relationship**

 Early science acknowledged two basic types of substances: beneficial ones (e.g. foods and medicines), and harmful ones such as those that cause sickness or death later regarded as poisons. Modern science disregarded this division saying it is not justified. Paracelsus opined that ‘‘the right dose makes the difference between a poison and a remedy.’’ Many chemical substances or mixtures display a whole lot of effects, ranging from beneficial through neutral to lethal. The effect of these substances depends not only on the quantity of the substance to which an organism is exposed, but also on the species and size of the organism, their nutritional status, the method of exposure, and several related factors. Dose is the amount of a chemical substance needed to produce an adverse effect. Response is defined as noticeable or observable effect induced by a chemical.

 For example if an alcohol is taken in small quantity, it may be harmless and sometimes even medically recommended. But, an overdose causes intoxication and, in extreme cases, death. Relating the biological effect of a chemical to its dose requires that there must be a measurable range between concentrations that cause no effect and those that produce the maximum effect. This is because various species do exhibit marked differences among individuals in response to chemicals. Therefore, the effect produced in an individual organism may not necessarily be the same in another. For this reason, any meaningful estimation of the toxic potency of a compound will involve statistical approach of evaluation. Due to the fact that toxicity of a chemical is related to the size of the exposed organism, dose therefore must be defined in terms of concentration rather than absolute amount.

**Dose – Response Curve**

The word dose implies the total amount of a chemical administered to an organism whereas the term dosage includes a characteristic feature of the organism, body weight or surface area. Dosage is more precise, and can therefore be related to other organisms, e.g. mg substance/kg body weight. We can put it therefore as dosage–response relationships. The normal way to analyze and represent the dose–response relation is to determine the percentage of the organisms in a particular dosage or concentration group which show the response.

The **dose-response curve**is a graphical representation of the rates of response of a population to a range of doses of a substance. This graph typically has an "s" shape as shown below

|  |
| --- |
|  |

**Figure1**.

Biologic variation is the variation in size of response among test subjects in the same population given the same dose of drug. Graphical representation of dose-response curves of drugs studied under identical conditions can help compare the pharmacologic profiles of the drugs. The information obtained from this helps to determine the dose necessary to achieve the desired effect. Based on these variations the following categories exist: Lethal Dose (LD), Inhibition Concentration (IC), and Effective Concentration (EC).

### Comparison of Dose-Response Curves for Drugs X, Y, and Z

|  |  |
| --- | --- |
| Drug X shows greater biologic performance per dosing equivalent and is therefore more potent than drug Y or Z. Drugs X and Z display equal efficacy, showed by their maximal attainable response (ceiling effect). Drug Y has more potential than drug Z, but with a lower maximal efficacy. Comparison of Dose-Response Curves for Drugs X, Y, and Z |  |

##### **Figure 2.**Knowledge Check

1. The quantity of a substance administered to an individual over a period of time or in several individual doses is known as the:

administered dose

absorbed dose

total dose

.

2. Fractionation of a total dose so that the total amount administered is given over a period of time usually results in:

decreased toxicity

increased toxicity

3. The usual dosage unit that incorporates the amount of material administered or absorbed in accordance with the size of the individual over a period of time is:

PPM/hour

mg/kg/day

kg/100 lb/week

4. The dose at which a toxic effect is first encountered is called the:

median toxic dose

absorbed dose

threshold dose

5. The dose-response relationship helps a toxicologist determine:

whether exposure has caused an effect

the threshold dose

the rate of increasing effect with increasing dose levels

all of the above

**11a. What are the full meanings of the following based on quantitative risk assessment?**

1. NOEL b. LOEL c. NOAEL d. LOAEL e. RFD
2. NOEL – No Observed Effect Level in mg/Kg/day: this is the highest dose which does not result in any observable biological effect.
3. LOEL – Lowest Observed Effect Level: this is the lowest experimentally obtainable dose rate.
4. NOAEL – No Observed Adverse Effect Level: this is the lowest dose which does not give a statistically significant adverse effect.
5. LOAEL- Lowest Observed Adverse Effect Level: this is the lowest achievable dose that yields a significant adverse effect.
6. RFD: Reference Dose ꓿ NOEL/UF where UF stands for Uncertainty Factors. This is used to determine allowable/ permissive exposure level.

## Conclusion

This study has established the fact that all substances in the environment can be examined for their beneficial or toxicity roles. What makes the difference between these two roles is the dose. Paracelsus established that only the dose makes the poison. This means whether a chemical substance will produce a beneficial effect or adverse effect it is a function of the dose. Various factors that affect toxicity of a chemical substance have been discussed. Clearly, it is not the entire dose administered to an organism that produces the noticeable effect. The ADME (Absorption, Distribution, Metabolism, and Excretion) process plays an important role in determining the actual dose that produces the effect. Part of the dose actually gets metabolized in the body system. Decision making bodies all over the world explore the data obtained from dose-response relationship to generate the exposure limit values for various chemicals.

**Recommendation**

Compromises in maintaining recommended standards most especially in the manufacture of medicines and other household chemical consumables have resulted in various health hazards and even death in many cases, mostly in the developing nations. On this, the governments at various levels in the country need to do more in the areas of creating awareness, regulations and enforcement of standards. Individuals can help self by getting acquainted with data specifying permissible exposure levels of various substances in order to serve as guidelines to lifestyles, things and places to avoid. This is because every substance is a potential poison if overdose.

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